Long-term monitoring of the glaciers in Wordie Bay, Antarctic Peninsula, using multi-mission SAR time series

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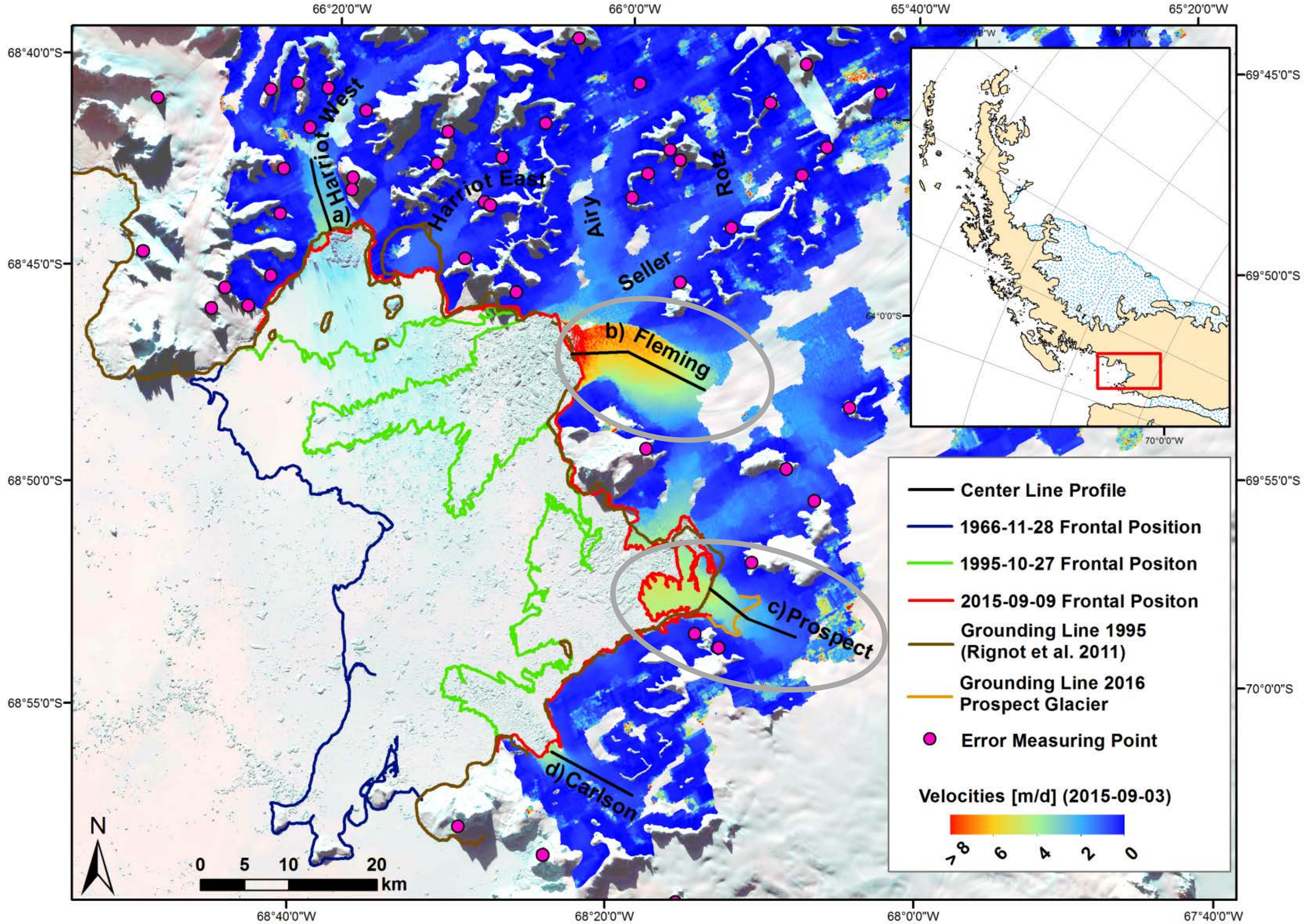
1. Overview of the Study Area: Wordie Ice Shelf



Surface velocities were derived from Sentinel-1 acquisitions (2015/08/28 and 2015/09/09).

Background image: mosaic of Landsat-8 LandsatLook „Natural Color“ images from 2015/09/16 ©USGS

2. Motivation & Research Questions

- What we know from other studies: acceleration of Fleming Glacier after disintegration of the ice shelf and dynamic thinning (Rignot et al. 2005, Wendt et al. 2010)

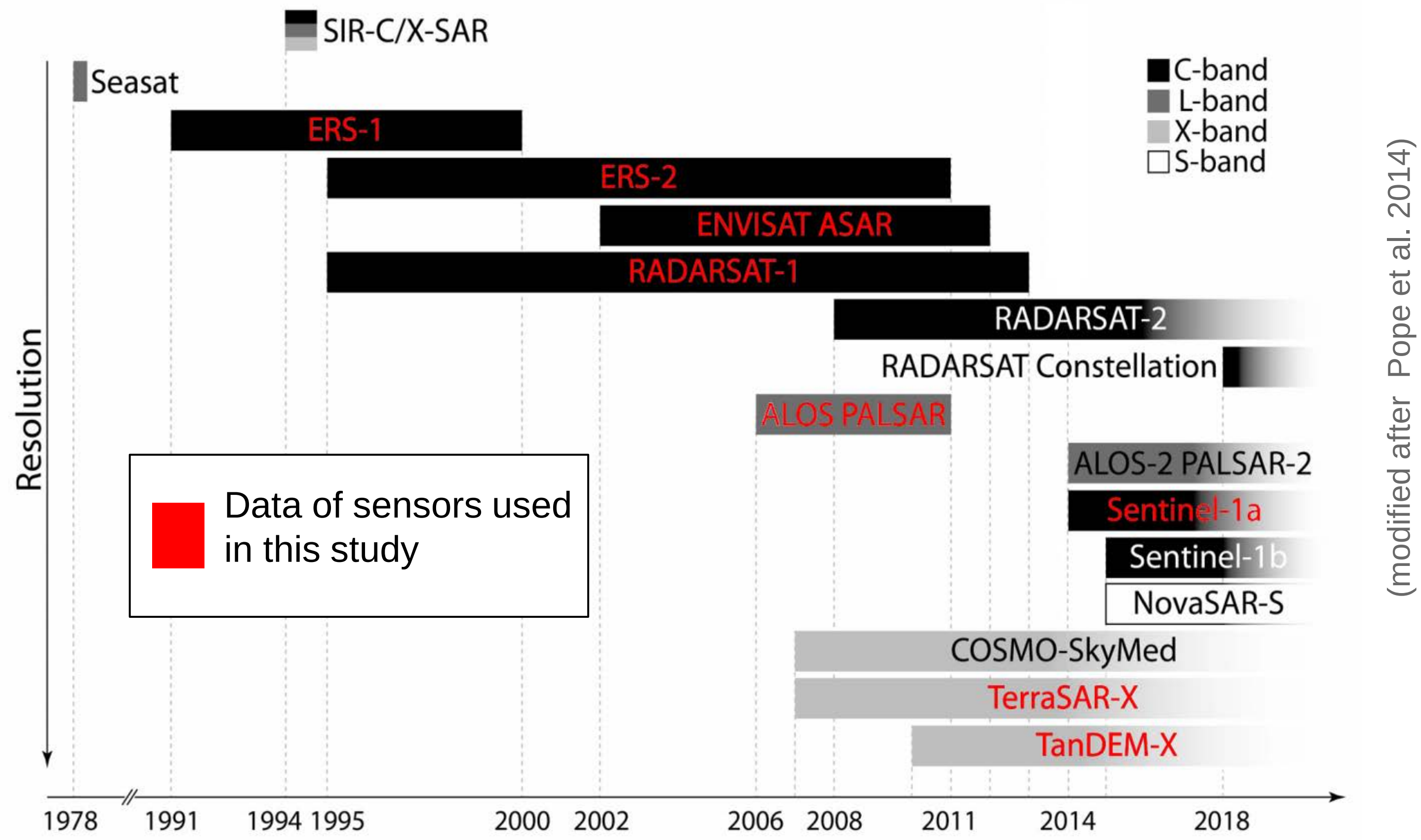
- No long-term studies which address the adaption process of the former tributary glaciers to the loss of the buttressing ice shelf

- How can multi-mission SAR data be used in order to derive long time series of datasets of glaciological parameters (e.g. velocities, ice elevation, mass balances,…) at Wordie Bay?

- How did these parameters change after the disintegration of the ice shelf exactly over time and how long do these changes last?

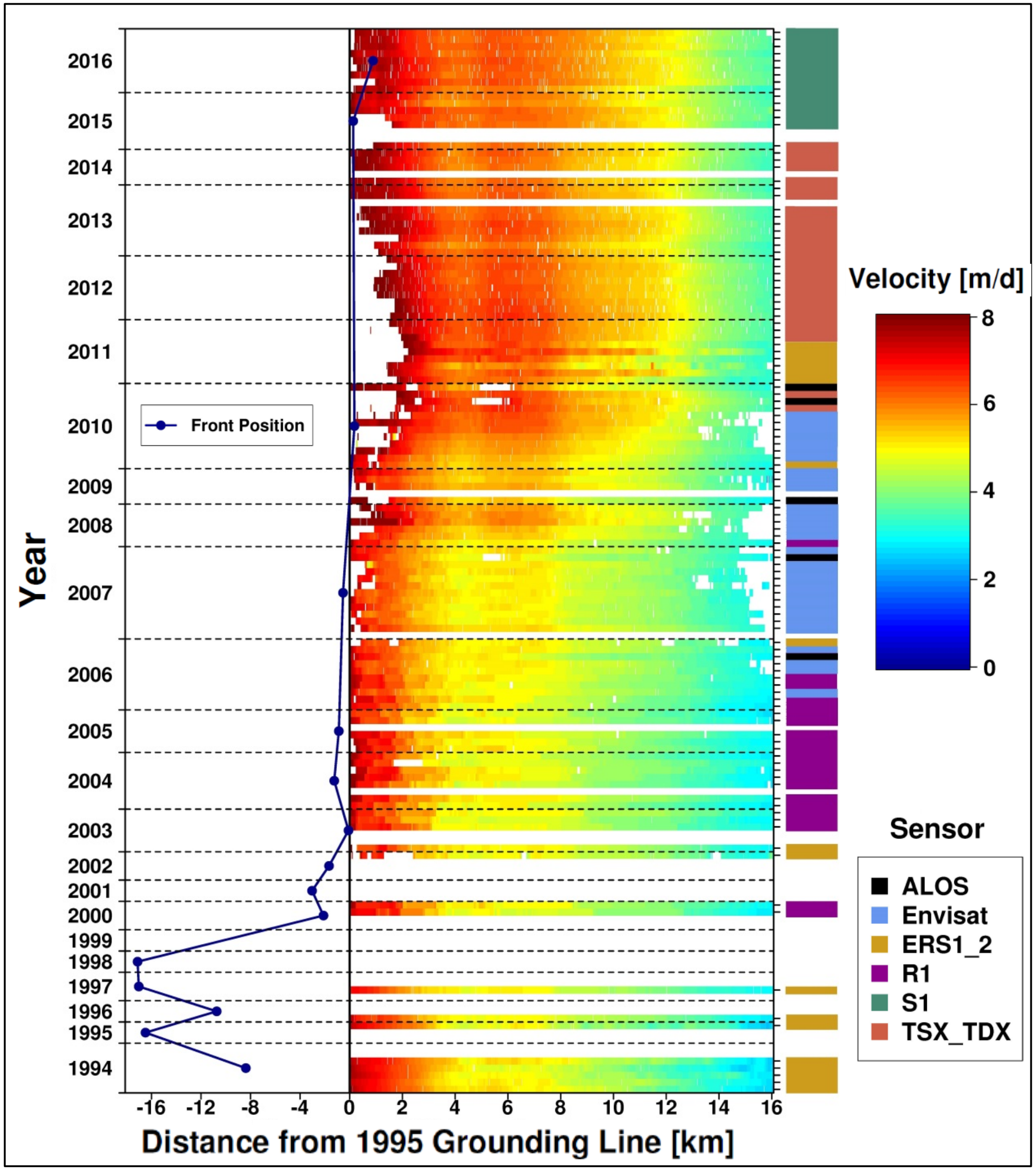
- Are there differences in the behavior of the single glaciers?

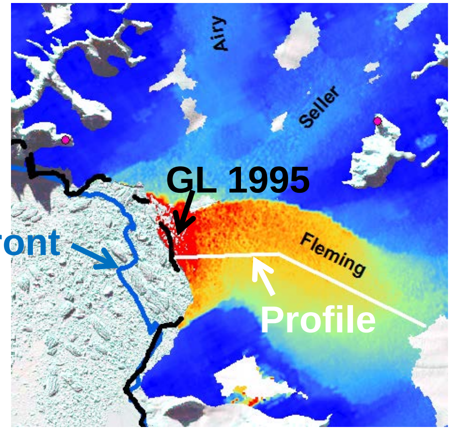
3.Velocity Measurements
a) Data & Methods



- **440 scenes** from **8 SAR-sensors**, covering a timespan from **1994 – 2016** were processed
- Glacier surface velocities were derived by applying SAR-feature tracking to image pairs with suitable temporal baselines

3.Velocity Measurements
b) Results: Fleming Glacier





- Stable velocities from 1994 to 2008
- In the end of 2008 sudden acceleration of the glacier and strong upstream propagation of high velocities
- At the same time the glacier front remained comparatively stable
- Rapid retreat of the grounding line due to oceanic melt (+ 1°C at 150 m, Cook et al. 2016), continuous dynamic thinning and a retrograde bed topography
- Big part of the tongue can freely float → loss of drag, highest speeds on floating parts

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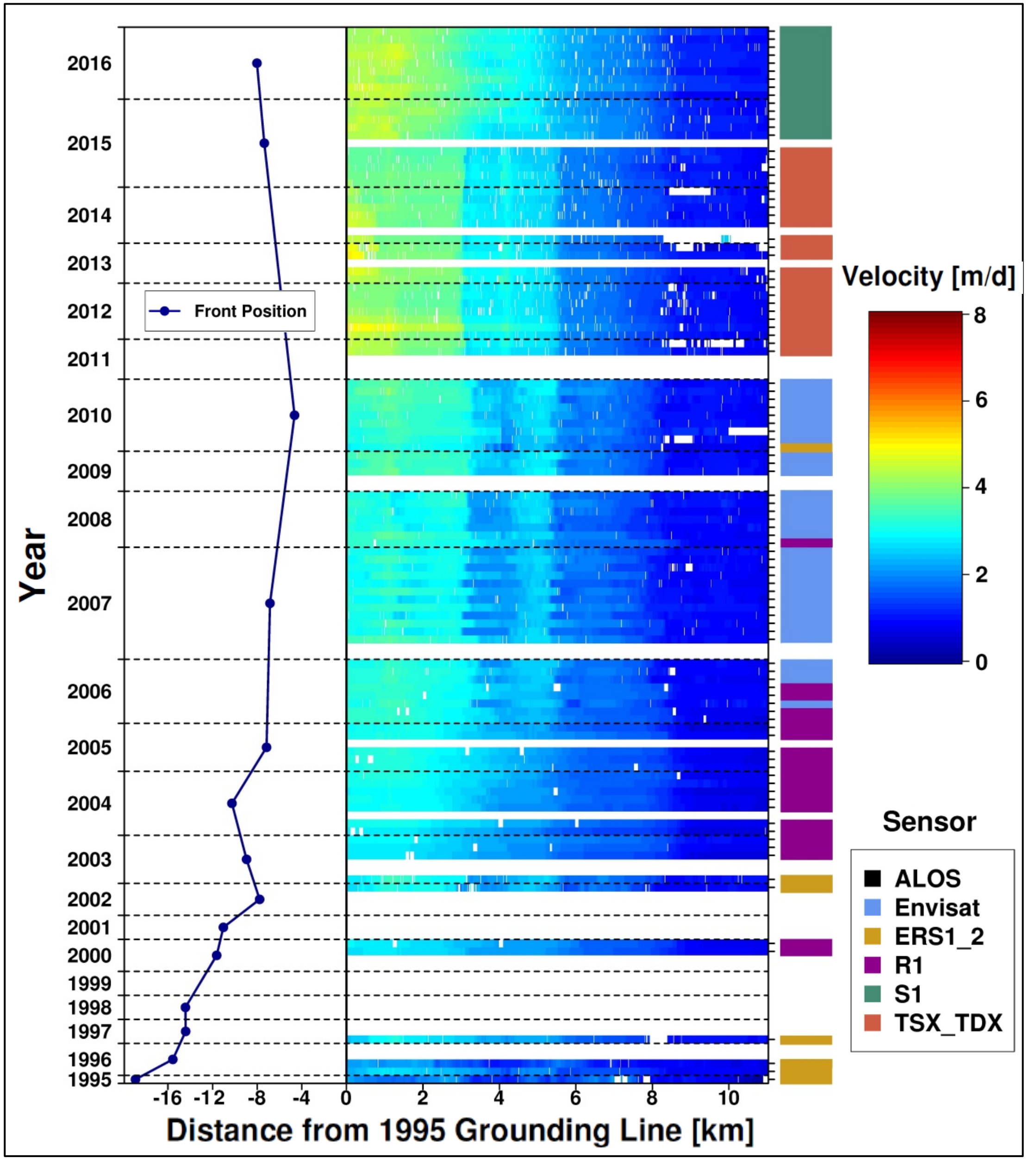
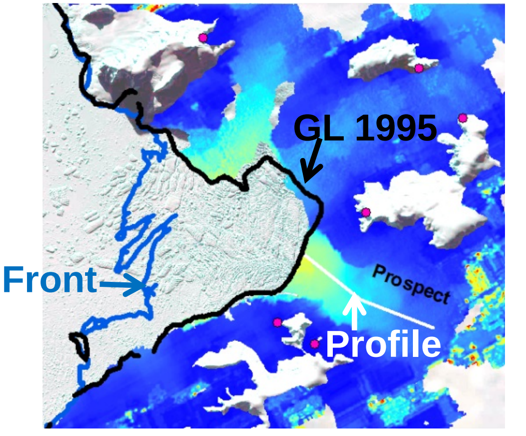
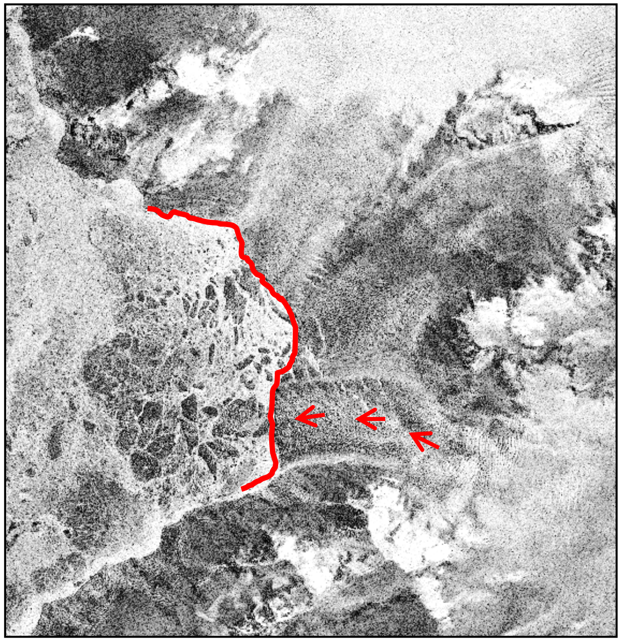
3.Velocity Measurements
b) Results: Prospect Glacier



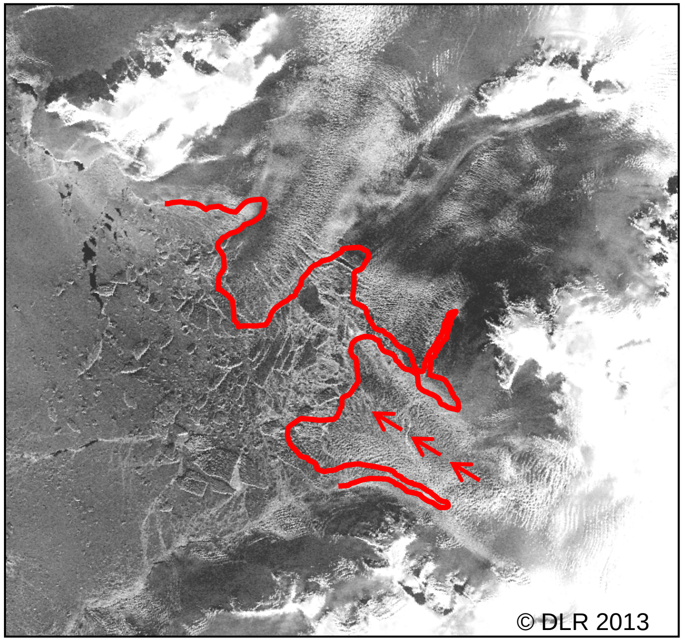


- Area loss between 1995 and 2010 → increase in ice velocities and an upstream extension of higher velocities due to diminished buttressing
- In the end of 2011 pronounced acceleration on the first 4 km of the profile
- Area and front distance remain quite stable at the same time
- In contrast to Fleming Glacier, loss of buttressing force as possible reason

3.Velocity Measurements
b) Results: Prospect Glacier



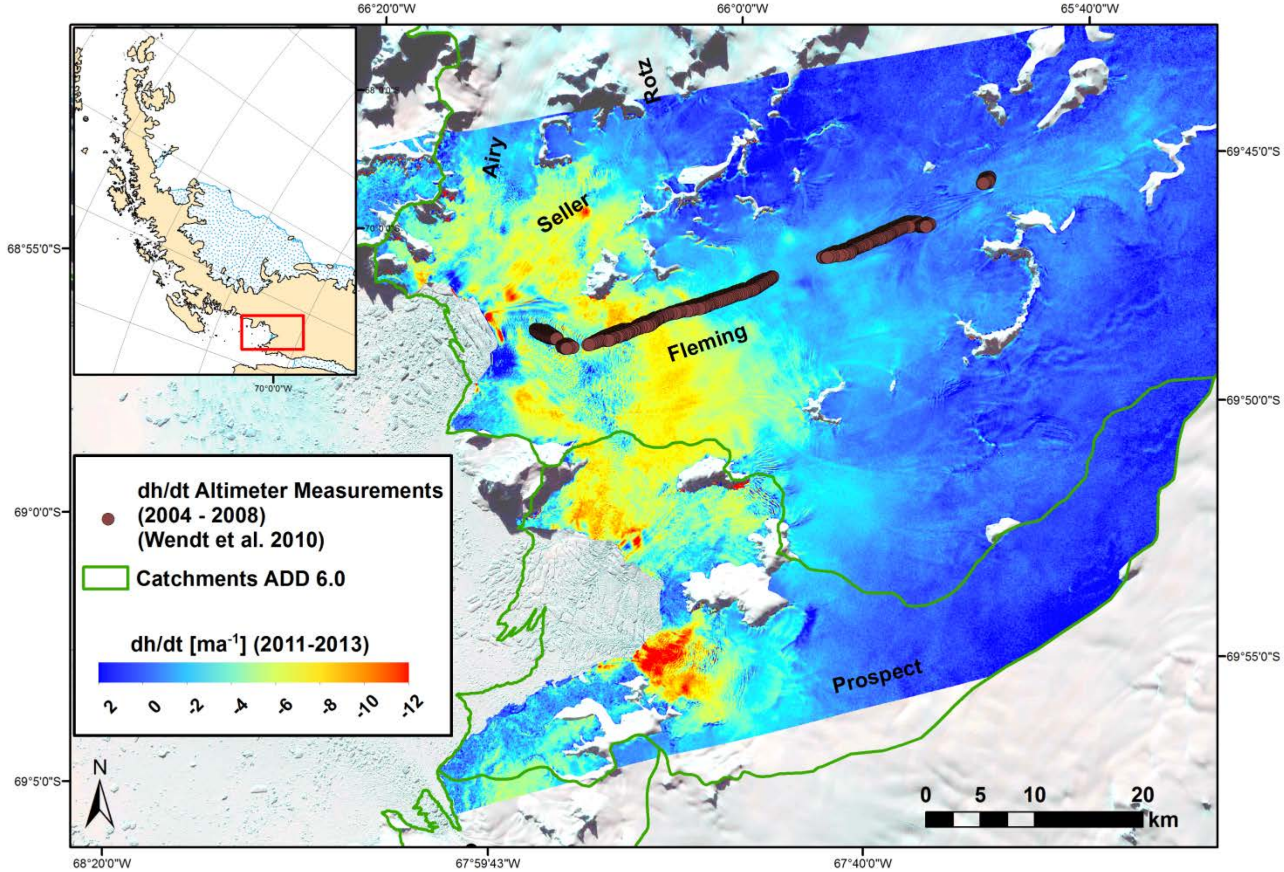
ERS-2 image from 2010-03-17



TerraSAR-X image from 2013-02-13

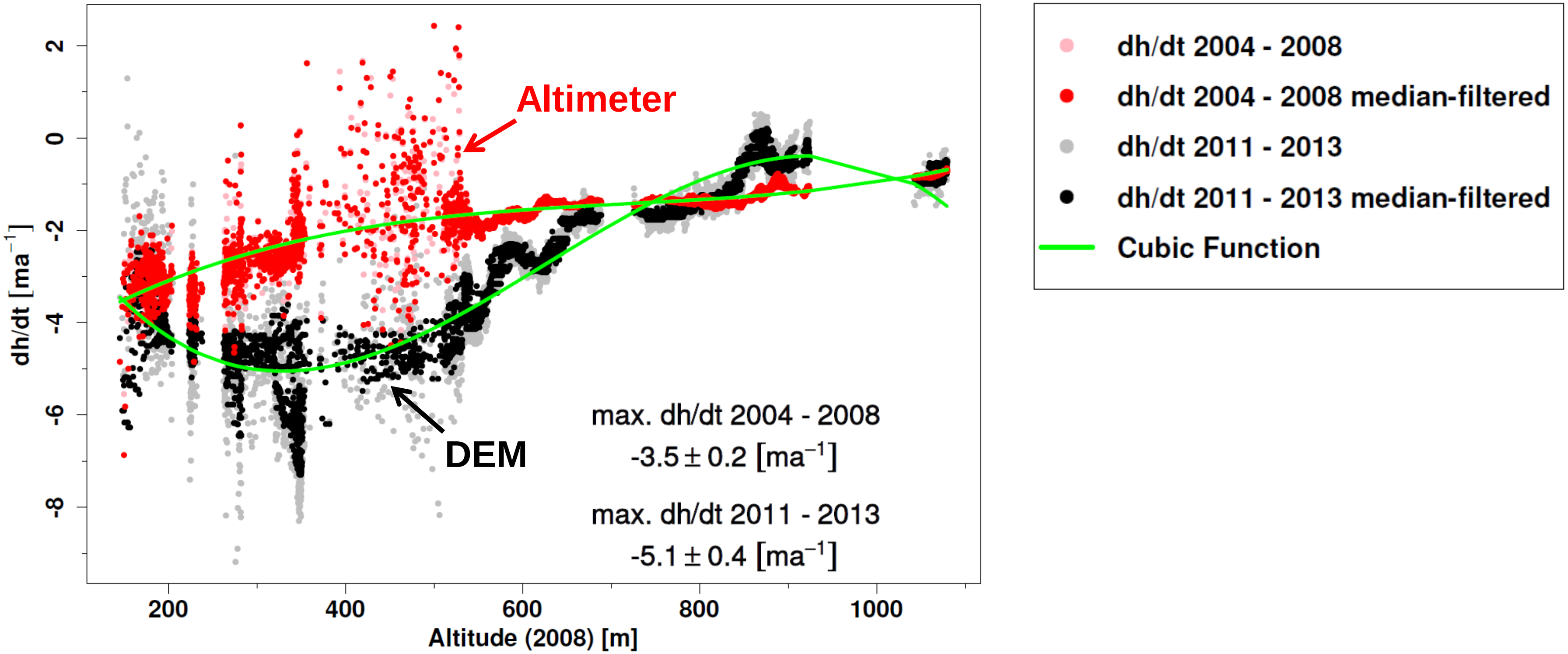
- Before the acceleration took place, the 3 branches of Prospect Glacier shared 1 front → tongues were interconnected
- When the acceleration took place, the interconnection got lost, 3 unconfined tongues developed, flow direction changed → buttressing got lost

4. Elevation Change
a) Data & Methods



- Differencing of two interferometric DEMs, generated from 8 TSX-TDX bistatic acquisitions in December 2011 and December 2013
- The 2013 DEM was vertically referenced to the 2011 DEM on sea level, tide differences were compensated by using the TPOX8 tide model (Egbert & Erofeeva, 2002)
- On Fleming Glacier comparison of the differential DEM-data with an elevation change rate profile for 2004 - 2008 from airborne laser altimeter data (Wendt et al. 2010)

4. Elevation Change
b) Results: Fleming Glacier



- The maximum height change rate increased from -3.5 ±0.2 [ma^{-1}] to -5.1 ±0.4 [ma^{-1}], and can now be found at approx. 380 m
- Highest thinning rates have propagated inland, maybe together with the migration of the grounding line
- Above 800 m, the ice thinning rates for 2011 – 2013 are smaller than for 2004 – 2008 → increase in snow accumulation

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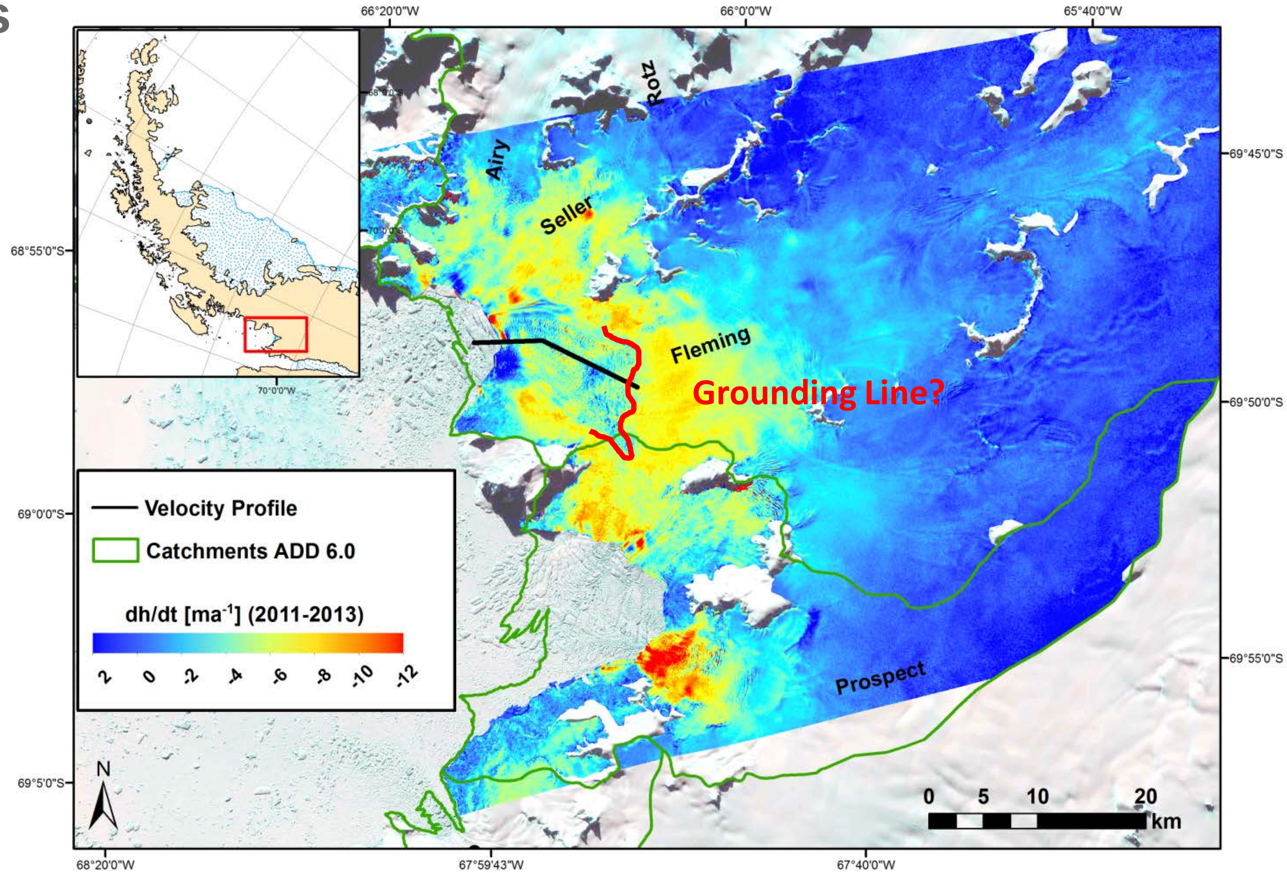
4. Elevation Change
b) Results



- Since ice thinning rates on Fleming Glacier may be highest upstream of the new grounding line due to more horizontal stretching caused by the faster flow → delineation of the possible new grounding line
- The delineated floating part of the tongue coincides with the extent of the highest velocities on the velocity profile
- Prospect Glacier shows the highest thinning rates of the area (up to 12 ma^{-1}). Together with the increase in flow speeds this can be interpreted as a sign of pronounced dynamic thinning.

Summary

- After the complete loss of the buttressing ice shelf and an acceleration, the **flow speeds of Fleming Glacier remained stable for decades**

- Continuous dynamic thinning and ocean melt in connection with an appropriate bed topography may have caused a **sudden retreat of the grounding line** of Fleming Glacier

- This may have caused a big part of the ice tongue to go afloat and therefore to **accelerate**

- The glaciers at Wordie Bay seem to be at **different stages** in response to the loss of the former ice shelf

- Prospect Glacier was **still influenced by the buttressing effect** of the remains of the former ice shelf → additional acceleration and strong dynamic thinning after recent ice break ups

- Fleming Glacier however had already to adapt to **new boundary conditions which were not solely connected to the disintegration of the former ice shelf** anymore

Thank you for your attention!

Paper on the presented results in preparation!

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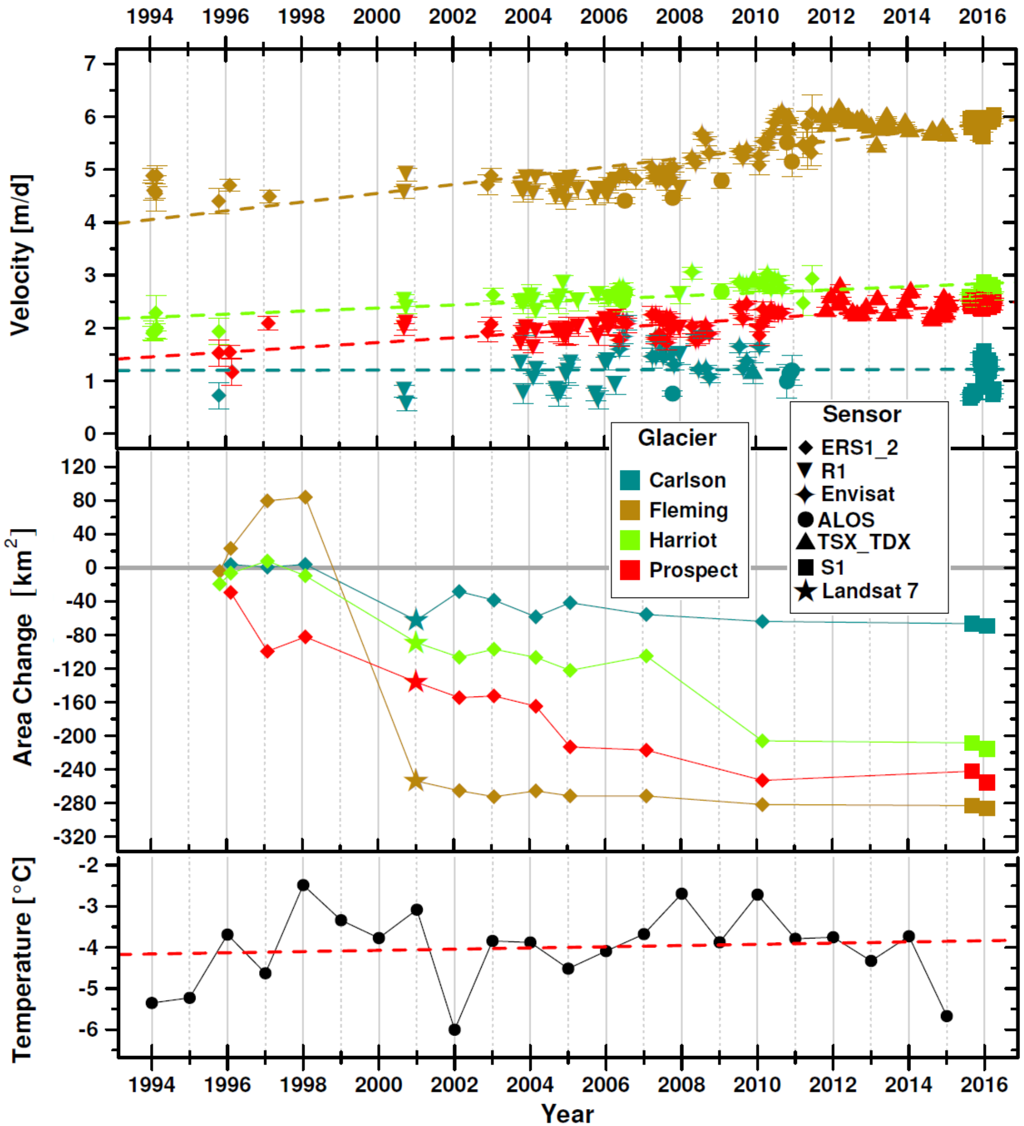
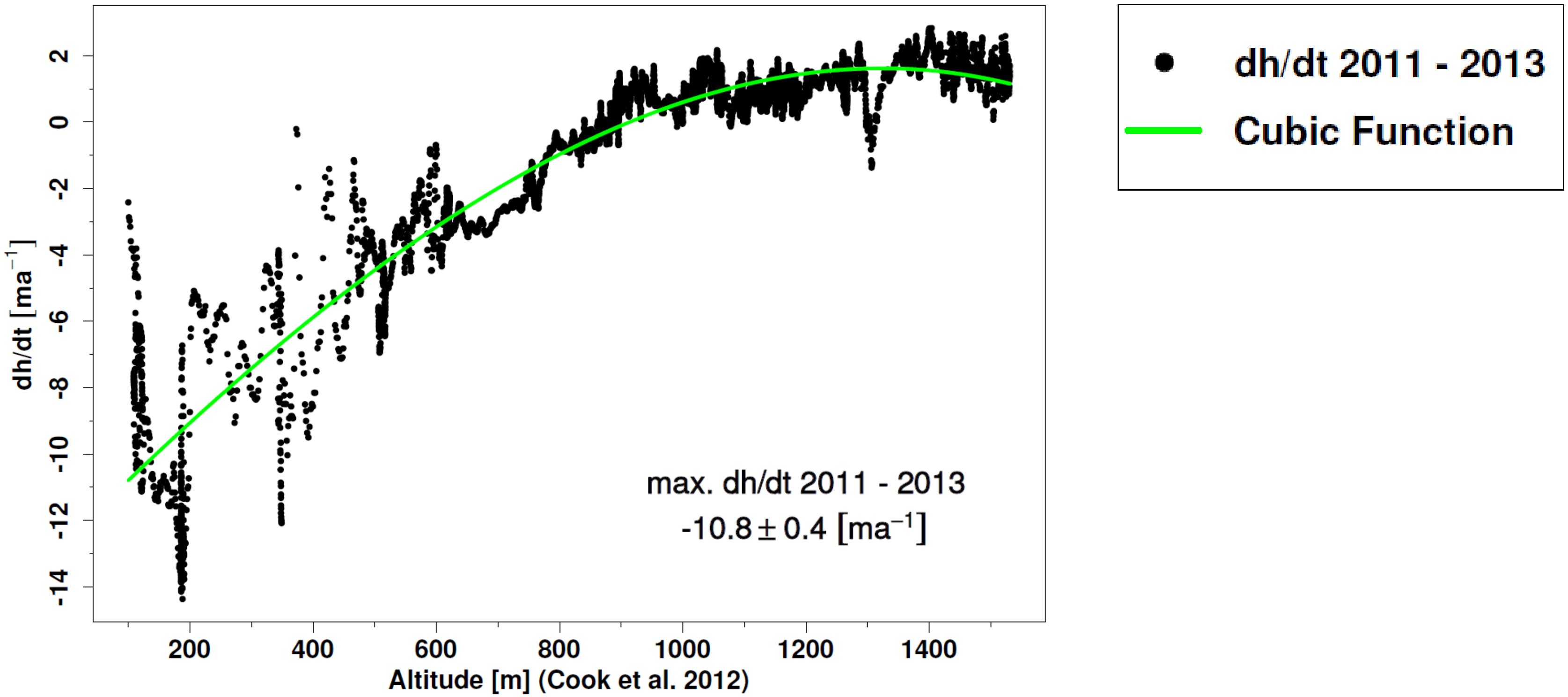
3.Velocity & Area Measurements
b) Results

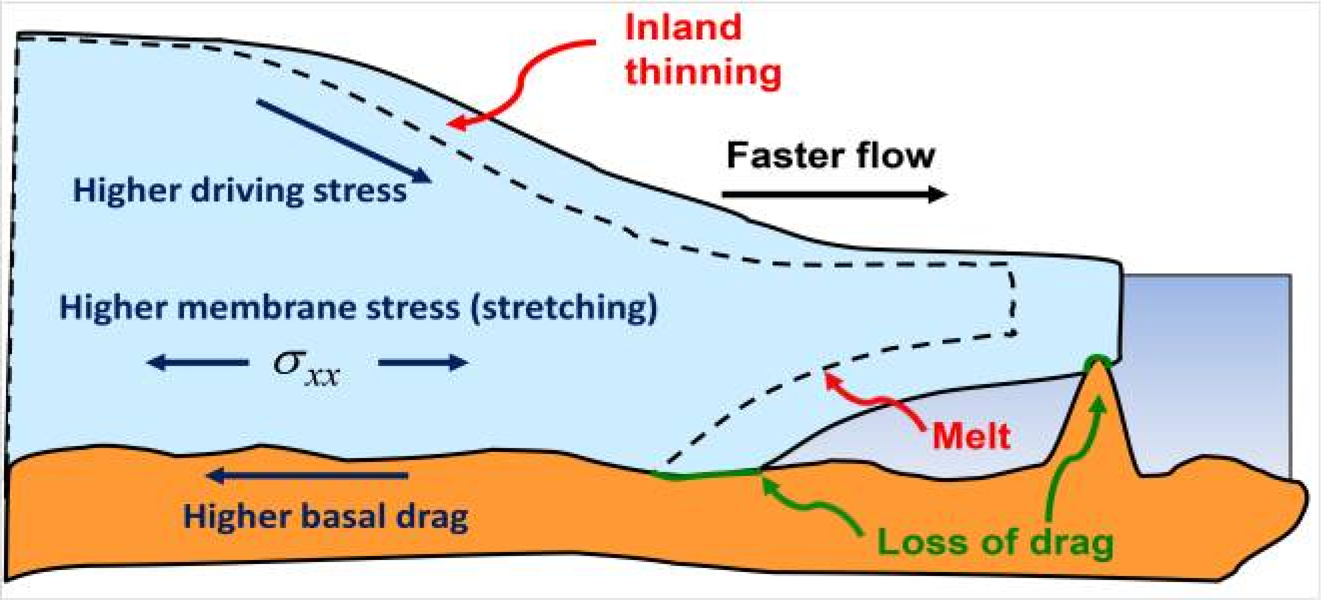


- Positive yearly trend of the median velocity for **Fleming (≈ 8 cm/day)** , **Prospect (≈ 4 cm/day)**, **Harriot (≈ 3 cm/day)**
- Carlson Glacier shows no velocity-trend
- Fleming Glacier lost approx. 350 km² of its unconfined tongue between 1998 – 2000 => no effect on velocities
- All Glaciers lost area, but glacier extents seem to be more stable at least since 2010
- Air temperatures at Rothera Station (170 km from Wordie Bay) show just a small positive trend
- Ocean temperatures at 150 m depth rose at up to +1°C at Wordie Bay (Cook et al. 2016) => dominant driver for the glacier front behavior

4. Elevation Change
a) Results

Prospect Glacier





https://www.bas.ac.uk/wp-content/uploads/2015/07/rob-iceshelve.jpg, 16.08.2016